Background and Status of Q1FY16 Global Implementation

April 20, 2015

"Where America's Climate, Weather, Ocean and Space Weather Services Begin"

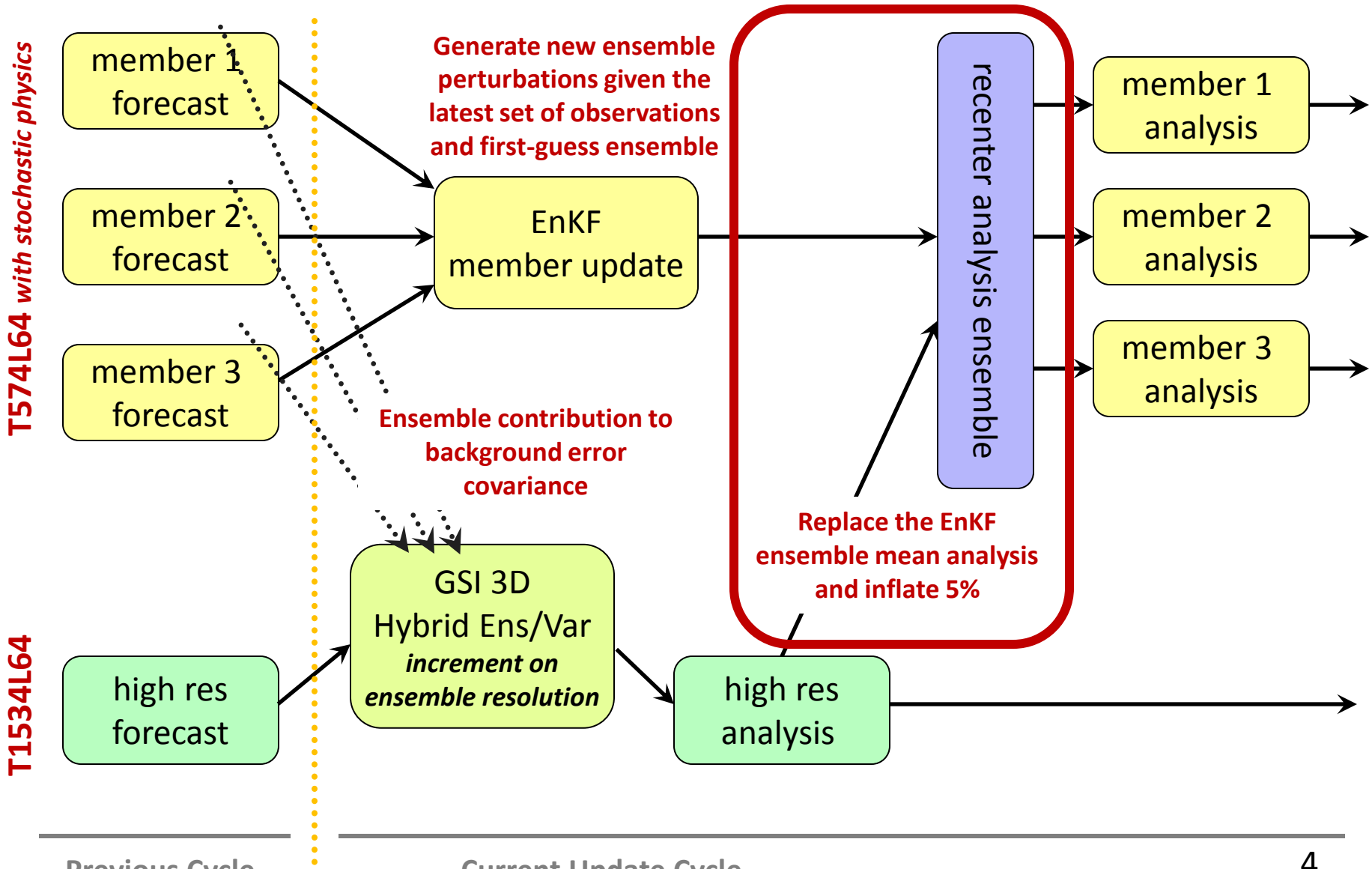
Background

Taken from presentation by Rahul Mahajan et al. @ WWOSC 2014 Montreal

Ensemble-Var methods: nomenclature

- ***En-4DVar***: Propagate ensemble $\mathbf{P^b}$ from one assimilation window to the next (updated using EnKF for example), replace static $\mathbf{P^b}$ with ensemble estimate of $\mathbf{P^b}$ at start of 4DVar window, $\mathbf{P^b}$ propagated with tangent linear model within window.
- ***4D-EnVar***: $\mathbf{P^b}$ at every time in the assimilation window comes from ensemble estimate (TLM no longer used).
- As above, with ***hybrid*** in name: $\mathbf{P^b}$ is a linear combination of static and ensemble components.
- ***3D-EnVar***: same as 4D ensemble Var, but $\mathbf{P^b}$ is assumed to be constant through the assimilation window (current NCEP implementation).

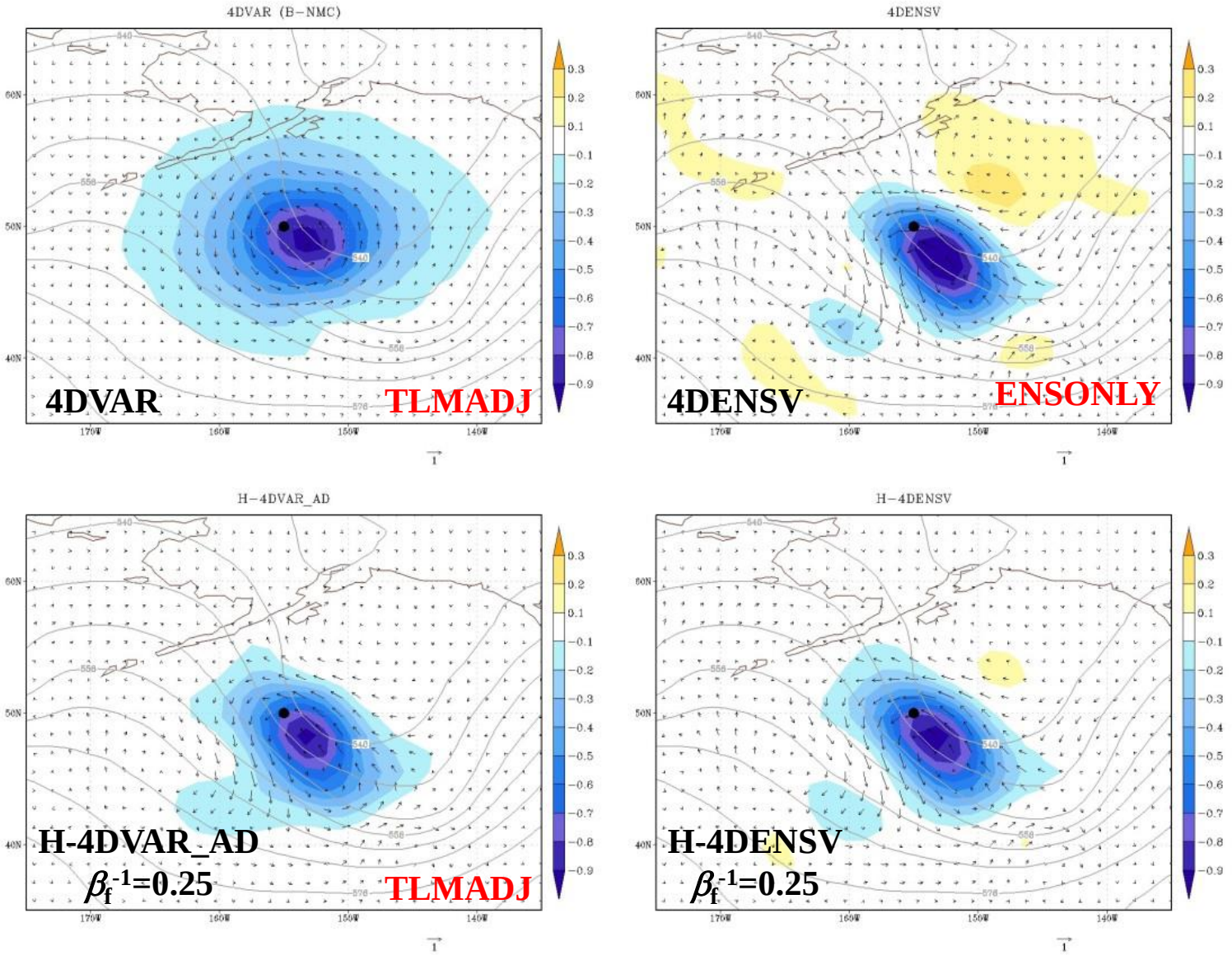
Current 2015 Dual-Res Coupled Hybrid Var/EnKF Cycling



Hybrid 4D EnVar

- Natural extension to operational 3D EnVar
  - Uses variational approach with already available 4D ensemble perturbations
- No need for development of maintenance of TLM and ADJ models
  - Makes use of 4D ensemble to perform 4D analysis
  - Modular, usable across a wide variety of models
- Highly scalable
  - Aligns with technological/computing advances
- Computationally inexpensive relative to 4DVAR (with TL/AD)
  - Estimates of improved efficiency by 10x or more, e.g. at Env. Canada (6x faster than 4DVAR on half as many cpus)
- Compromises to gain best aspects of (4D) variational and ensemble DA algorithms
- Other centers exploring similar path forward for deterministic NWP
  - Canada (potentially replace 4DVAR), UKMO (potentially replace En4DVar)

Single Observation (-3h) Example for 4D Variants

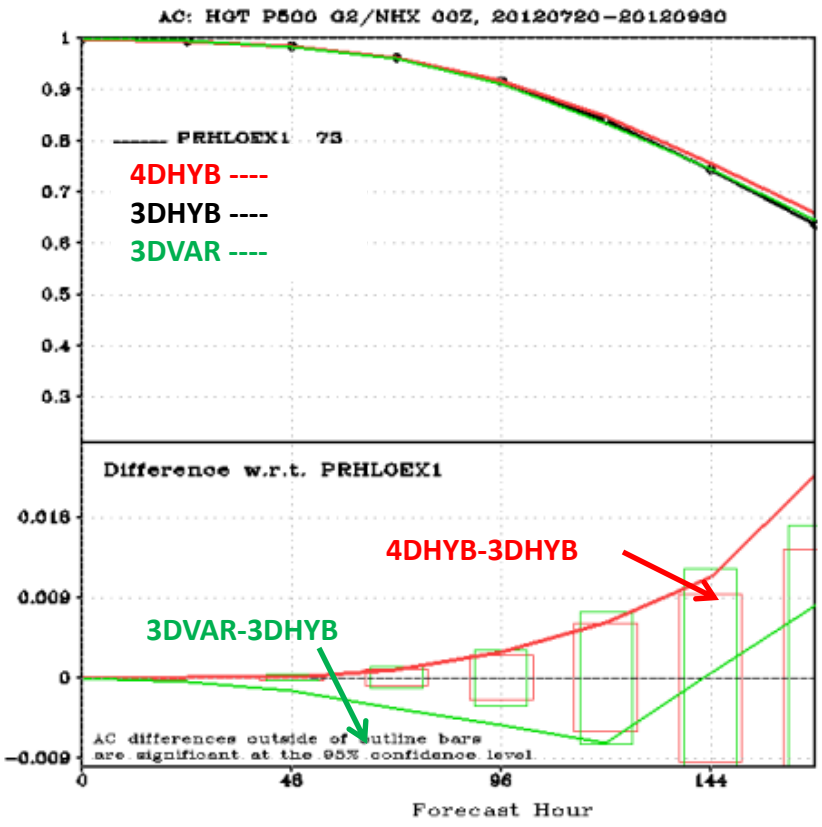


Low Resolution GFS/GDAS Experiments with real observations

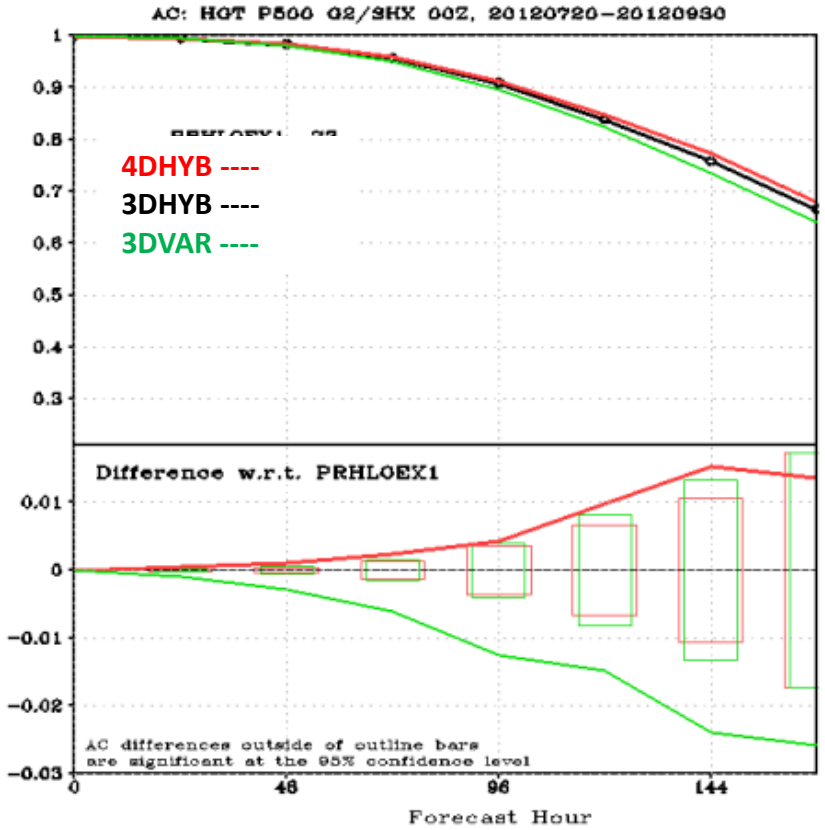
- Basic configuration
  - T254L64 GFS, opnl obs, GFS/GDAS cycles 20120701-20121001
- **PR3LOEX0**
  - **3DVAR**
- **PRHLOEX1**
  - **Hybrid 3D EnVar**, 80 member T126L64 ensemble with fully coupled (two-way) EnKF update, slightly re-tuned localization and inflation for lower resolution, TLNMC on total increment, 75% ensemble & 25% static
- **PRH4DEX1**
  - **Hybrid 4D EnVar**, TLNMC on all time levels, only 1x150 iterations
  - Hourly TC relocation, O-G, binning of observations

500 hPa Die Off Curves

Northern Hemisphere



Southern Hemisphere

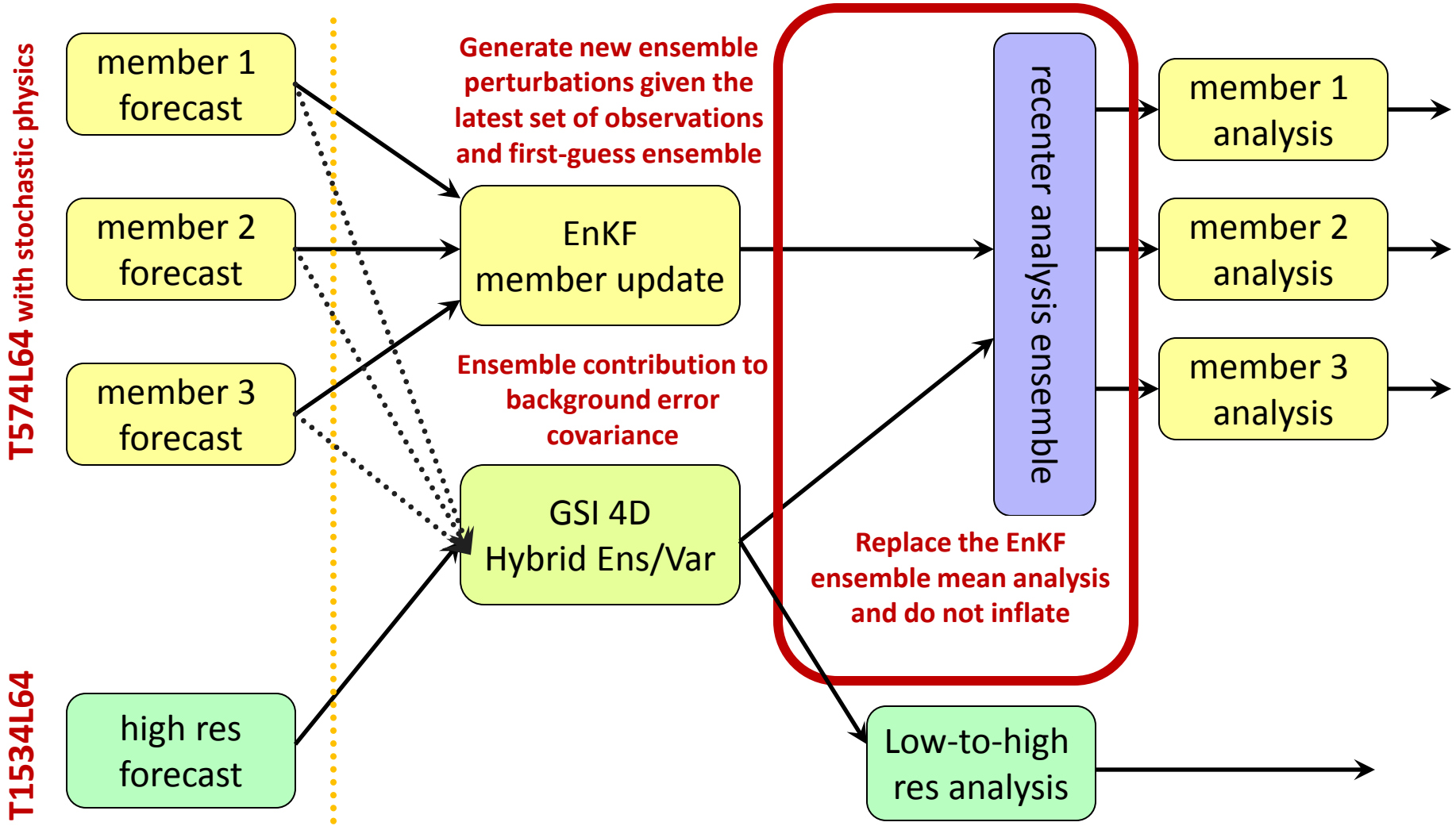


Move from 3D Hybrid (current operations) to Hybrid 4D-EnVar yields improvement that is about 75% in amplitude in comparison from going to 3D Hybrid from 3DVAR.

(Preliminary) Results and Comments

- 4D extension has positive impact in OSSE and real observation (low resolution) framework
- 4D EnVar does have slower convergence
- As configured, 4D EnVar was 40% more expensive than 3D hybrid (caveats being different iteration count, low resolution and machine variability)
  - ***TLNMC (balance constraint) over all time levels quite expensive***
  - I/O potential issue, optimization is needed prior to implementation.
    - Option to post-process ensemble prior to use in assimilation in subsequent cycle

Proposed 2016 Dual-Res Coupled Hybrid Var/EnKF Cycling



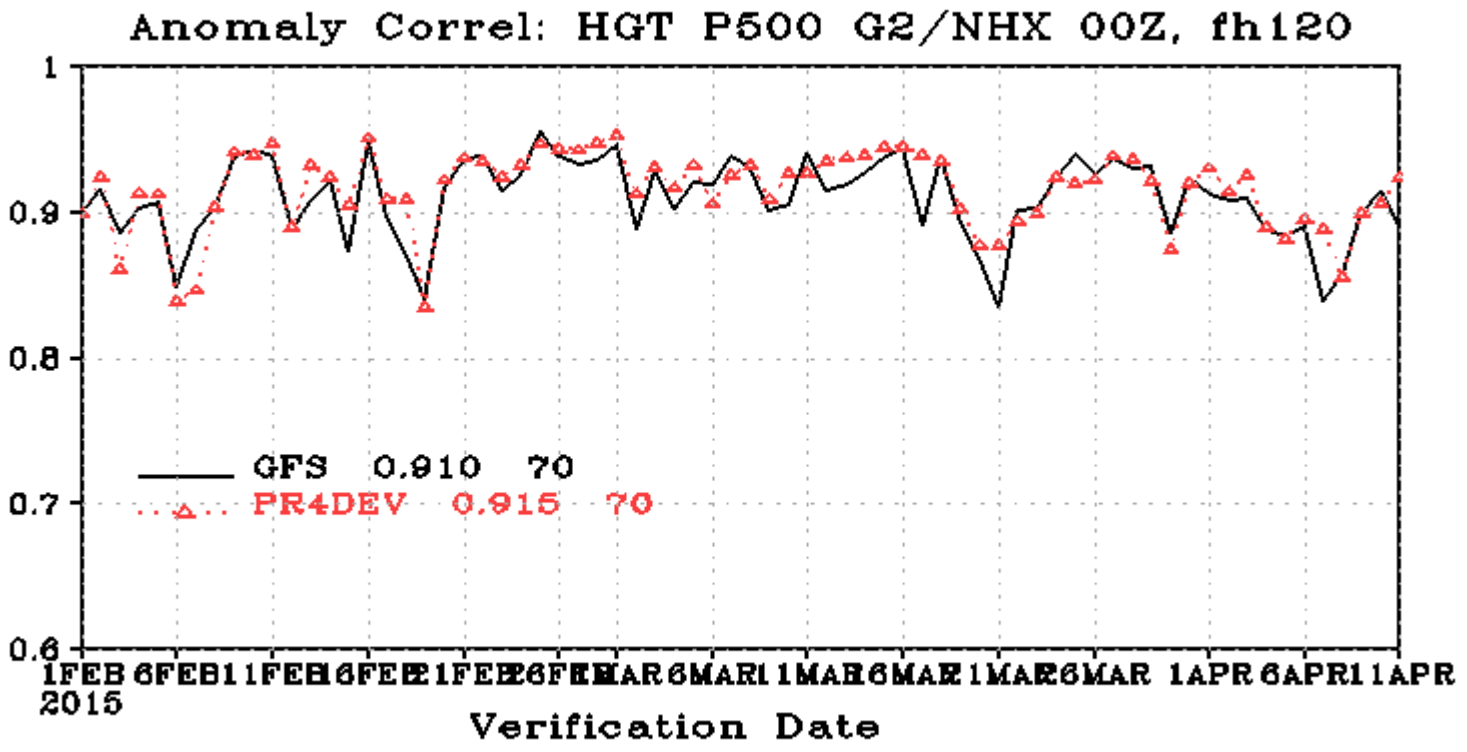
Status

Based on real-time WCOSS parallels

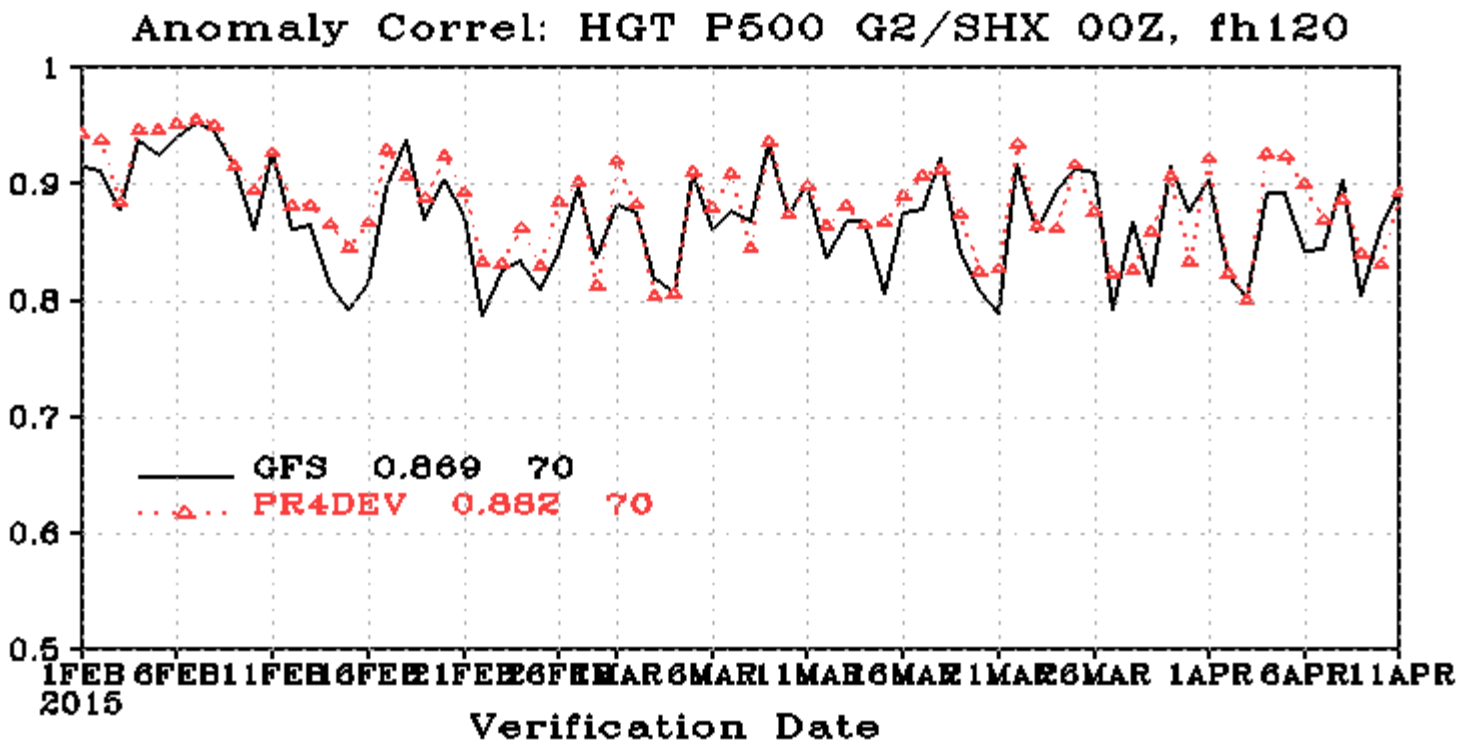
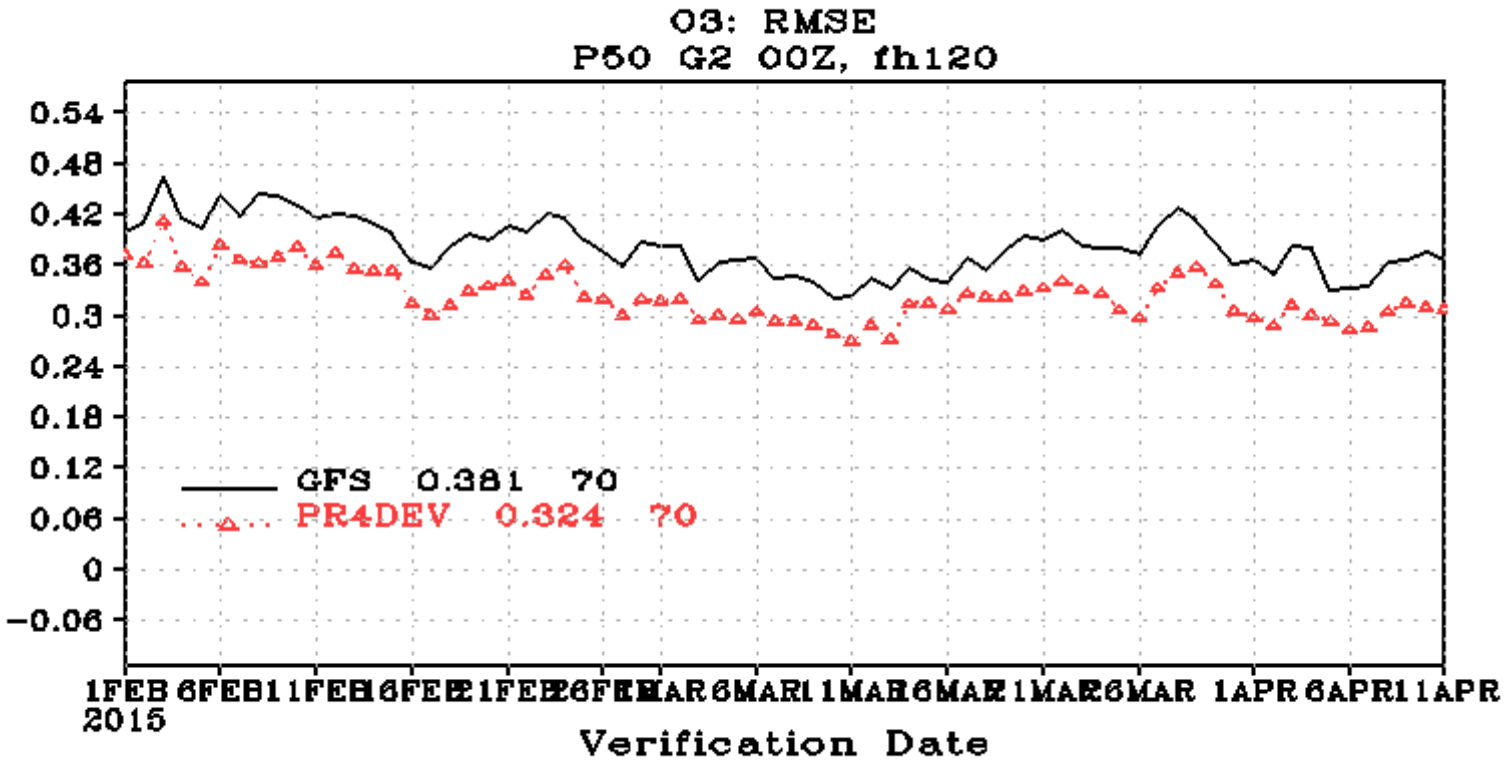
Status summary

- Q1FY16 Analysis status table - "living" DA status log
- Real-time parallel (pr4dev) – phase 1 nodes
  - Evolving parallel with components added as ready
  - Includes
    - Hourly hybrid 4D-EnVar
    - Multivariate ozone assimilation
    - Observations: aircraft data bias correction and moisture assimilation, atmospheric motion vector QC and thinning improvements
    - Forecast model: resolution independent stochastic physics parameters (self scaling); IAU updates
  - Not yet included
    - CRTM v2.2, All-sky radiance assimilation, NSST
  - pr4dev statistics
- Second intermediate parallel for testing new components (prtest) – phase 2 nodes
  - Currently testing IAU, all other components identical to pr4dev
  - prtest statistics

pr4dev – 500mb NH AC



pr4dev – 500mb SH AC



pr4dev – 50 RMS ozone - Global